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PLEISTOCENE RADIOLARIA FROM THE KERGUELEN PLATEAU, LEG 119, SECTIONS 1H AND 2H

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ABSTRACT

Twenty core samples from the Leg 119 Site 745 (Sections 1H to 2H) on the Kerguelen-Heard Plateau in the Southern Ocean region yielded, thirty-eight well-preserved radiolarian taxa which were studied and illustrated. The systematics, biostratigraphy, distribution in the core and comparison with radiolarian occurrences from other regions are presented. Two radiolarian zones are established viz. Psi and Omega in the sections. Ten new species are described but not formally named. The primary purpose of this paper is to present a first detailed Antarctic Pleistocene radiolarian data and refined biozone boundaries for comparative studies with other parts of the Antarctic region.

Keywords: Pleistocene radiolaria, Biostratigraphy, Antarctic Continental Margin

INTRODUCTION

The first detailed work on Pleistocene radiolaria mainly deals with taxonomy, morphological variations, radiolarian biozonation and comparison with other regions of the Southern Ocean regions.

Significant numbers of radiolarians were recovered from the two sections of Leg119 Site 745 of the Ocean Drilling Project (Fig.1). The area of present study is located on a large sediment drift at the base of the Southern slope of the Kerguelen Plateau at 59°35.71'S and 85°57.60'E. The samples were collected at a water depth of 4082.5 m. The interval between the studied samples is 1.5 m but varies if lithology changes. The core with a total length of 14.11m. contains diatom ooze along with radiolarians in traces. The sedimentary structures like burrows, mottles and laminae are present. The Leg119 Site 745 is divided lithostratigraphically into two units, i.e. unit I and II. Further, unit I is subdivided into subunits IA and IB. However, the studied sections lie in the subunit IA (Fig.2).

The Southern Ocean Radiolarians are represented by diverse assemblages that are distinctly different from lower-latitude assemblages. Knowledge of the Antarctic radiolarians of the continental margin of the Southern Ocean region is very scanty. Ehrenberg (1844b) reported twenty species from the Antarctic sector of the Indian Ocean in the Southern Ocean region. Haecker (1908) described few radiolarian species from the plankton samples collected off South of Africa. Popofsky (1908) carried out the study on the radiolarians from the Wilhelm II Coast of Antarctica and the Kerguelen Island. Riedel (1958) studied the radiolarian species from sediment samples collected during the B.A.N.Z. Antarctic Research Expedition. Nakaseko (1959) reported Antarctic radiolarian species from the Super-family Liosphaericae. The detailed studies based on piston cores and Deep Sea Drilling Project rotary drilled sections (Chen 1974, 1975a, 1975b; Hays and Opdyke, 1967; Keany and Kennett 1972; Keany, 1976, 1979; Lombari and Lazarus, 1988; Petrushevskaya, 1967, 1975; Weaver, 1976a, 1976b) provided illustrations and descriptions of common radiolarian species and established Neogene radiolarian stratigraphy. Furthermore, Riedel and Sanfilippo (1970,1971), Kling (1971), Theyer *et al.* (1978) and Riedel and Westberg (1982) carried out work on Neogene radiolarian biostratigraphy of the Southern Ocean region. Hays (1965) reported radiolarians from late Tertiary and Quaternary of the Antarctic seas and described biostratigraphy of this region. Moreover, Cenozoic radiolarian biostratigraphy of the deep-sea cores from Southern Ocean region was carried out by Hays (1967, 1970), Bandy and Casey (1969) and Hays and Berggren (1971). Petrushevsksya (1971) established radiolarian zones of Quaternary and Upper Tertiary deposits of middle Asia. Petrushevskaya (1972 a, b, 1973, 1978), Chen (1974, 1975a), Weaver (1975) and Weaver *et al.* (1976) carried out the detailed study on Antarctic biostratigraphy and palaeoclimate. Keany and Kennett (1975) studied the Pliocene - Pleistocene radiolarian biostratigraphy and palaeoclimatic history from the samples collected near the Antarctic and Subtropical convergence of the Southern Ocean region. Nakaseko and Nishimura (1982) carried out the study on the bottom sediments of the Bellingshausen Basin in the Antarctic sea. Weaver (1983), Abelmann and Gersonde (1988) and Lazarus (1990) worked on core sections from the Falkland Plateau and Weddell Sea and established Neogene biostratigraphy of the Antarctic region. Gersonde *et al.* (1990) did the study on radiolarian biostratigraphy and magnetography of siliceous microfossils from Antarctic sediments. Caulet (1991) introduced two new genera and seventeen new species from Neogene samples of the Kergueleen Plateau. Barron *et al.* (1991) studied the biochronology and magnetostratigraphy of the Antarctic sediments. A detailed report was presented on the Neogene radiolaria from ODP Legs 119 and 120 by Lazarus (1992). McIntyre and Kaczmarska (1996) worked on the sections of ODP, Site 745 in the Kerguelen Plateau and placed *Stylatractus universus* Hays at the base of the Omega zone at 24.8- 24.4 mbsf. Lazarus (2002) studied and described environmental control of radiolarian diversity, evolutionary rates and taxa longevities of the Antarctic Neogene radiolarian from ODP Leg 119. Sharma *et al.* (2004) carried out the detail study on Pleistocene sediments of Tasman region and reported 83 radiolarian taxa. Sharma *et al.* (2006) established two radiolarian zones of Tasman region. Sharma and the Takahashi (communicated) reported 75 radiolarian species from the Pleistocene sediments of SE Indian area of the Antarctic Continental margin. Sharma and Takahashi (*in press*) established one radiolarian zone, i.e. lower and upper Chi for the Antarctic

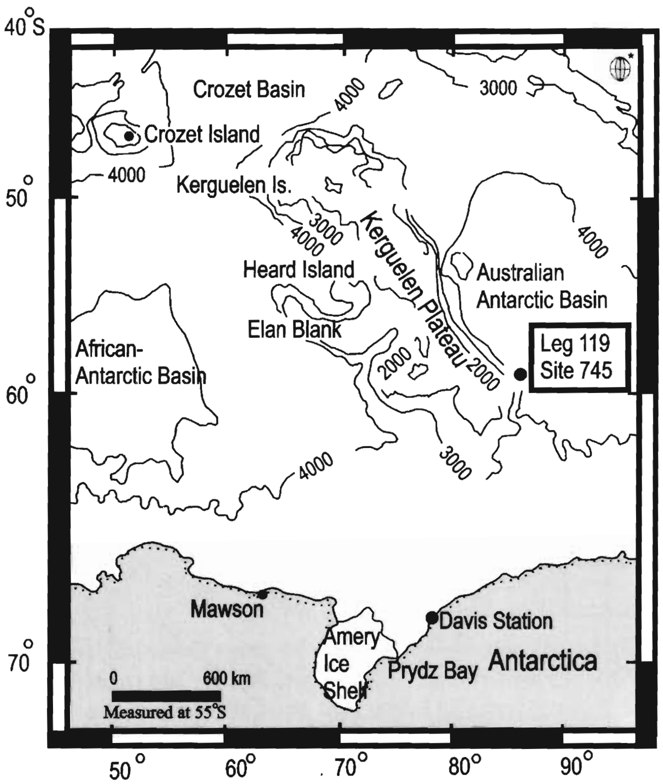


Fig. 1. Location of the studied piston core.

Continental margin.

MATERIAL AND METHODS

In the present study, 20 samples from Leg 119, Site 745 were taken. The total length of the studied section is 14.11 m. Sediment samples of about 3-4g were disaggregated in dilute Hydrogen peroxide (H_2O_2) for 1-2 hour followed by heating to just below the boiling point. For dissolving calcareous material from the samples 10% HCL was added and later samples were kept at high temperature for another 1-2 hours. One teaspoonful of Calgon (Hexametaphosphate) was added to further disaggregate the sediment samples and complete the treatment. The samples were sieved through a 63 micron mesh sieve and dried. The strewn slides were prepared by using an eye dropper and Canada balsam as a mounting medium. Generally, minimum 2-3 slides (of cover slip size 22x22mm) were examined for taxonomic and stratigraphic work, depending on their abundance (i.e. generally between 500-700 individual radiolarians).

SYSTEMATICS DESCRIPTION

The classification of the subclass Radiolaria followed here is that of De Wever *et al.* (2001) along with Nigrini and Moore (1979); Nigrini and Lombari (1984) and Lazarus (1990). Remarks on observed morphological features and their modifications have been added for many taxa. Species within a genus and genera within a family are arranged alphabetically. Characteristic morphological features for each new species and those given in open nomenclature are described. The synonymy for each taxa is incomplete and consists of references of interest to the present study. The quantitative estimates of radiolarian abundance (VA=very abundant (>50%); A=abundant (20-50%); C=common (5-20%); F=few (0.5-5%); R=rare (<0.5%), but more than single specimen; +=single specimen; blank=absent) and preservation (G=good; M=moderate; P=poor) are indicated for each sample in Table 1. The microphotographs of all the identified species are illustrated in Plates I and II.

Phylum **Sarcodina** Hertwig and Lesser, 1874
Class **Actinopoda** Calkins, 1909
Subclass **Radiolaria** Müller, 1858
Order **Polycystina** Ehrenberg, 1875, *emend.* Riedel, 1967b
Suborder **Spumellaria** Ehrenberg, 1875.
Family **Collosphaeridae** Müller, 1858.
Genus ***Acrosphaera*** Haeckel, 1881

Acrosphaera sp. cf. *A. spinosa echinoides* (Haeckel)
(Pl. I, fig. 1)

Acrosphaera echinoids Haeckel, 1887, p.100, pl.8, fig.1.
Acrosphaera spinosa echinoids (Haeckel) Bjørklund and Goll, 1979, p.1311, pl.1, figs.7,10-13; pl.4, figs.1-4,7-8.

Remarks: This species differs from *Acrosphaera spinosa echinoides* (Haeckel) of Bjørklund and Goll (1979) in lacking small protuberances and alternating depressions on the surface of the shell.

Abundance: Very rare to few.

Distribution: This species is reported from the Tasman region as rare to abundant (Sharma *et al.*, 2004).

Acrosphaera sp. A
(Pl. I, figs. 2,8)

Description: Thick spherical lattice shell with pores irregularly spaced and irregular in size. Pores vary from small to large. The outer wall is slightly banded. Spines vary in size from tubular to conical. 40-44 pores present on shell surface.

Abundance: Very rare to few.

Acrosphaera sp. B
(Pl. I, fig. 5)

Description: Lattice shell spherical, thick walled. Pores are subcircular and irregular in size having 10-12 pores on half equator. The surface is characterized by cylindro-conical bladed spines which are of nearly equal in size.

Abundance: Very rare to few.

Family **Actinommidae** Haeckel, 1862, *emend.* Riedel, 1967a.
Genus ***Acanthoshaera*** Ehrenberg, 1859

Acanthosphaera sp.
(Pl. I, figs. 3,4)

Description: Single shell, surface spiny having long spines, pores irregular in size and closely packed.

Abundance: Very rare.

Genus ***Actinomma*** Haeckel, 1860 *emend.* Nigrini, 1967, emend. Bjørklund, 1977

Actinomma antarcticum (Haeckel)
(Pl. I, figs. 9,10)

Spongoplegma antarcticum Haeckel, 1887, p.90.
Actinomma antarcticum (Haeckel) Nigrini, 1967, p.26, pl.2, figs.1a -d.

Remarks: Hays (1965) observed that medullary meshwork may be present or absent but in the studied section, it is absent, may be due to dissolution.

Abundance: Rare to common.

Range: Pliocene to Pleistocene (Keany,1979).

Distribution: Lombari and Boden (1985) showed its distribution throughout the Southern Ocean region. Sharma

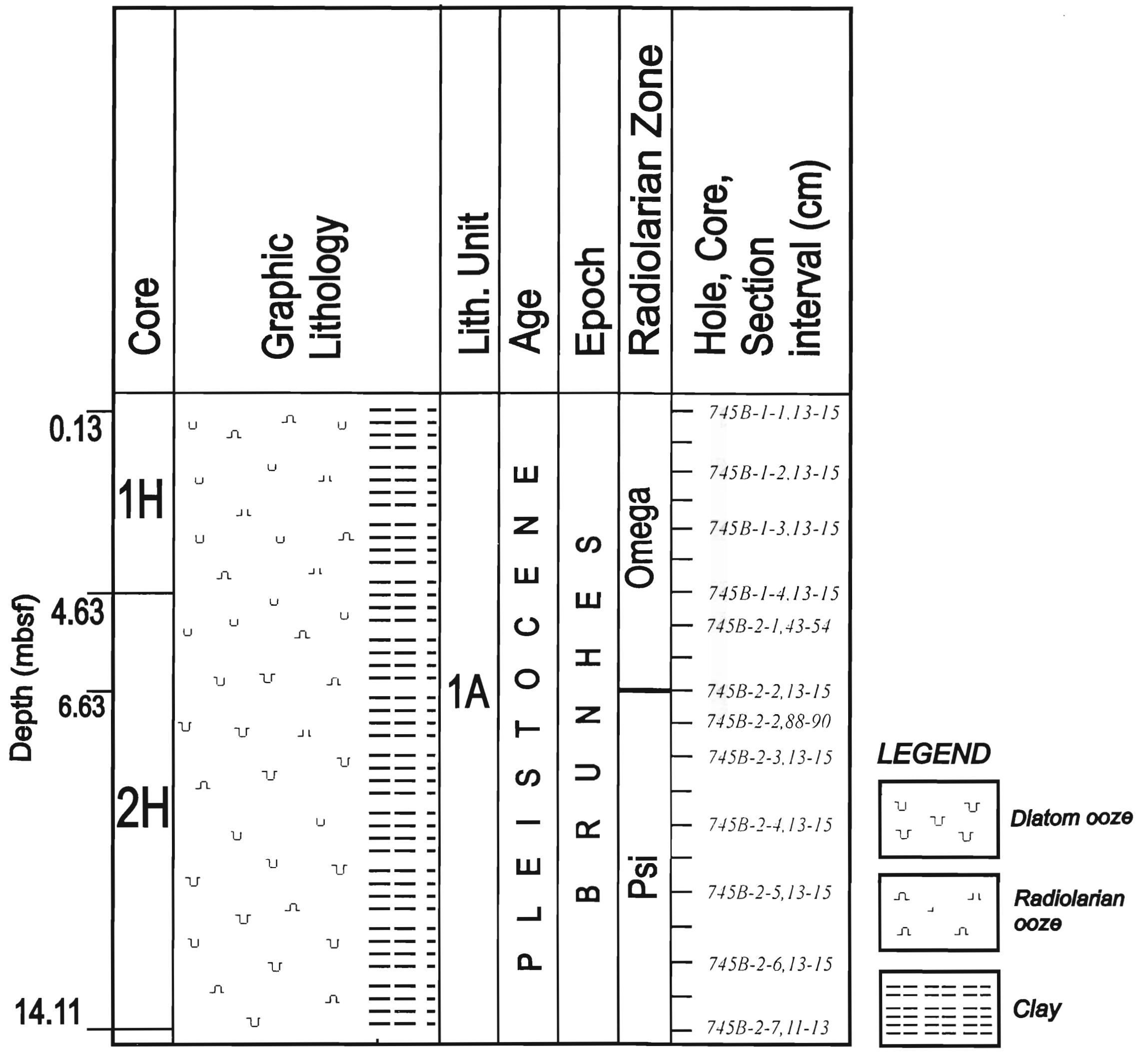


Fig. 2. Age, position of the samples, lithostratigraphic succession, Palaeomagnetic stratigraphy, depth and radiolarian zone of the Leg 119 site 745.

and Takahashi (*in press*) also showed its presence from very rare to few in this region.

Actinomma leptodermum (Jörgensen)
(Pl. I, figs. 11,12)

Echinomma leptodermum Jörgensen, 1900, p.57; 1905, p.116, pl.8, figs.33,a-c.

Actinomma leptodermum (Jörgensen)Nigrini and Moore, 1979, p.S35, pl.3, fig.7.

Abundance: Very rare to few.

Distribution: Presence in the Southern Ocean region (Lombari and Boden 1985). Sharma *et al.* (2004) reported its presence from rare to abundant in the Tasman region.

Genus ***Haliometta*** Haeckel, 1887
Haliommetta miocenica (Campbell and Clark)
(Pl. I, figs. 6,7)

Heliosphaera miocenica Campbell and Clark, 1944, p.16, pl.16, figs.10-14.

Haliommetta miocenica (Campbell and Clark) group, Petrushevskaya and Kozlova, 1972, p.517-519, pl.9, figs.8,9.

Remarks: Petrushevskaya and Kozlova (1972) could not differentiate between *Echinomma popofskii* Petrushevskaya, *Acanthosphaera* sp. Hays and *Echinomma quadrisphaera* Dogiel. Only the forms which have three concentric shells are included in *Haliometta miocenica* by the authors.

Abundance: Very rare to few.

Range: Pleistocene (Chen,1975).

Genus ***Heliosoma*** Haeckel, 1887
Heliosoma sp.
(Pl. II, fig. 12)

Description: Two shells are present, outer surface has 8-10 radial spines and numerous byspines. The surface has closely spaced subcircular to circular pores of varying size. Ten thin, radial beams connecting the inner to the outer shell.

Abundance: Very rare to few.

Genus ***Stylatractus*** Haeckel, 1887
Stylatractus universus Hays
(Pl. II, figs. 1,2)

Stylatractus sp. Hays, 1965, p.167, pl.1, fig.6.

Stylatractus universus Hays, 1970, p.215, pl.1, figs.1-2.

Remarks: Lazarus (1992) observed the base of Omega Zone as the LAD of *S. universus* and marked at 0.4 Ma in the Antarctic region.

Abundance: Very rare.

Range: Neogene (Keany,1979); Lazarus (2002) LO- 0.3, FO- 13.2Ma.

Distribution: Sharma *et al.* (2004) reported from rare to abundant in the Tasman region, and Sharma and Takahashi (*in press*) reported its presence from very rare to few in the Antarctic region.

Stylatractus sp.
(Pl. I, fig. 21)

Description: Shells ellipsoidal, consisting of three concentric lattice shells. Two unequal polar spines, heavy and somewhat cylindro-conical in shape. Innermost shell spherical, thin walled with subcircular pores. Second lattice shell thick walled, with large subcircular pores. The shells are joined by radial beams, outermost ellipsoidal, thick walled, spiny with large irregular pores.

Abundance: Very rare.

Family **Saturnalidae** Deflandre, 1953
Genus ***Saturnalis*** Haeckel, 1881
Saturnalis circularis Haeckel
(Pl. I, fig. 20)

Saturnalis circularis Haeckel, 1887, p. 131; Keany, 1979, p. 53, pl. 1, fig. 12, pl. 5, fig.4.

Abundance: Very rare.

Range: Chen (1975a) and Keany (1979) showed its occurrence from the Oligocene to the Lower Pleistocene.

Distribution: Sharma and Takahashi (in press) reported its presence from very rare to rare in the Antarctic region and Sharma *et al.*, (2004) showed its rare presence in the Tasman region.

Family **Sponguridae** Haeckel, 1862, *emend.* Petrushevskaya, 1975
Genus ***Spongocore*** Haeckel, 1887
Spongocore sp.
(Pl. II, fig. 3)

Description: Shell consists of a cylindrical, solid, spongy test with three joints separated by two constrictions. The middle joint is slightly larger than the length of the terminal joint. Radial spines have present on the surface of the terminal joints, while the middle joint has small unequal spines and irregular pores. The middle joint shows spongy appearance, while terminal joint a has closely spaced, concentric shell.

Abundance: Very rare.

Genus ***Spongurus*** Haeckel, 1860
Spongurus pylomaticus Riedel
(Pl. I, fig. 22)

Spongurus pylomaticus Riedel, 1958, p.226, pl1, figs.10,11; Nigrini and Moore, 1979, p.S65, pl.8, figs.3a-b.

Abundance: Very rare to common.

Range: Neogene (Keany,1979).

Spongurus sp.
(Pl. I, fig. 23)

Description: Shell ellipsoidal, spiral spongy arrangement is present. The surface of the shell bears small spines.

Remarks: Although the generic diagonosis given by Heackel (1862) for *Spongurus* does not encompass such forms with a spiral structure. Ling *et al.*, (1971) considered them within the present classification scheme.

Abundance: Very rare to few.

Family **Spongodiscidae** Haeckel, 1862, *emend.* Riedel, 1967b
Genus ***Spongaster*** Ehrenberg,1860.
Spongaster tetras Ehrenberg *irregularis* Nigrini
(Pl. I, fig. 19)

Spongaster tetras Ehrenberg *irregularis* Nigrini, 1967, p.43. pl.5, fig.2.

Abundance: Very rare to few.

Distribution: Nigrini (1967) and Sanfilippo *et al.* (1985) observed that *S. tetras irregularis* of rectangular forms occurs only in the higher latitudes.

Genus ***Spongopyle*** Dreyer, 1889
Spongopyle osculosa Dreyer
(Pl. I, fig. 13)

EXPLANATION OF PLATE I

1. ***Acrosphaera*** sp. cf. *A. spinosa echinoides* Haeckel , 745B-1H-1, 88-90; focussed on surface; x 100.

2,8. ***Acrosphaera*** sp. A, 745B-1H-2, 88-90; 2 focussed on outer portion; x 500, 8. focussed on inner portion; x 200.

3,4. ***Acanthosphaera*** sp., 745B-1H-1, 88-90; 3. focussed on outer portion 4. focussed on inner portion; x 200.

5. ***Acrosphaera*** sp. B, 745B-1H-2, 88-90; focussed on surface; x 100.

6,7. ***Haliommetta miocenica*** Campbell and Clark, 745B-1H-2, 13-15; 6 focussed on outer portion 7. focused on inner portion; x 200.

9,10. ***Actinomma antarcticum*** Haeckel, 745B-1H-1, 13-15; 9. focussed on inner portion 10. focussed on outer portion; x 200.

11,12. ***Actinomma leptodermum*** Jörgensen, 745B-1H-2, 88-90; 11. focussed on inner portion 12. focussed on outer portion; x 100.

13. ***Spongopyle osculosa*** Dreyer , 745B-1H-2, 88-90; focussed on surface; x 200.

14,15. ***Spongotrochus glacialis*** Popofsky, 745B-1H-2, 13-15; 14. focussed on surface; x 200, 745B-1-3H, 13-15; 15. focussed on surface; x 100.

16. ***Lithelius minor*** Jörgensen, 745B-1H-3, 13-15; focused on surface; x 200.

17. ***Stylodictya aculeata*** Jörgensen, 745B-1H-1, 13-15; focussed on surface; x 200.

18. ***Stylodictya validispina*** Jörgensen, 745B-1H-3, 13-15; focussed on surface; x 500.

19. ***Spongaster tetras*** Ehrenberg irregularis Nigrini, 745B-1H-1, 88-90; focused on surface; x 200.

20. ***Saturnalis circularis*** Haeckel, 745B-2H-1, 96-98; focused on surface; x 200.

21. ***Stylatractus*** sp., 745B-1H-2, 13-15; focussed on outer portion; x 200.

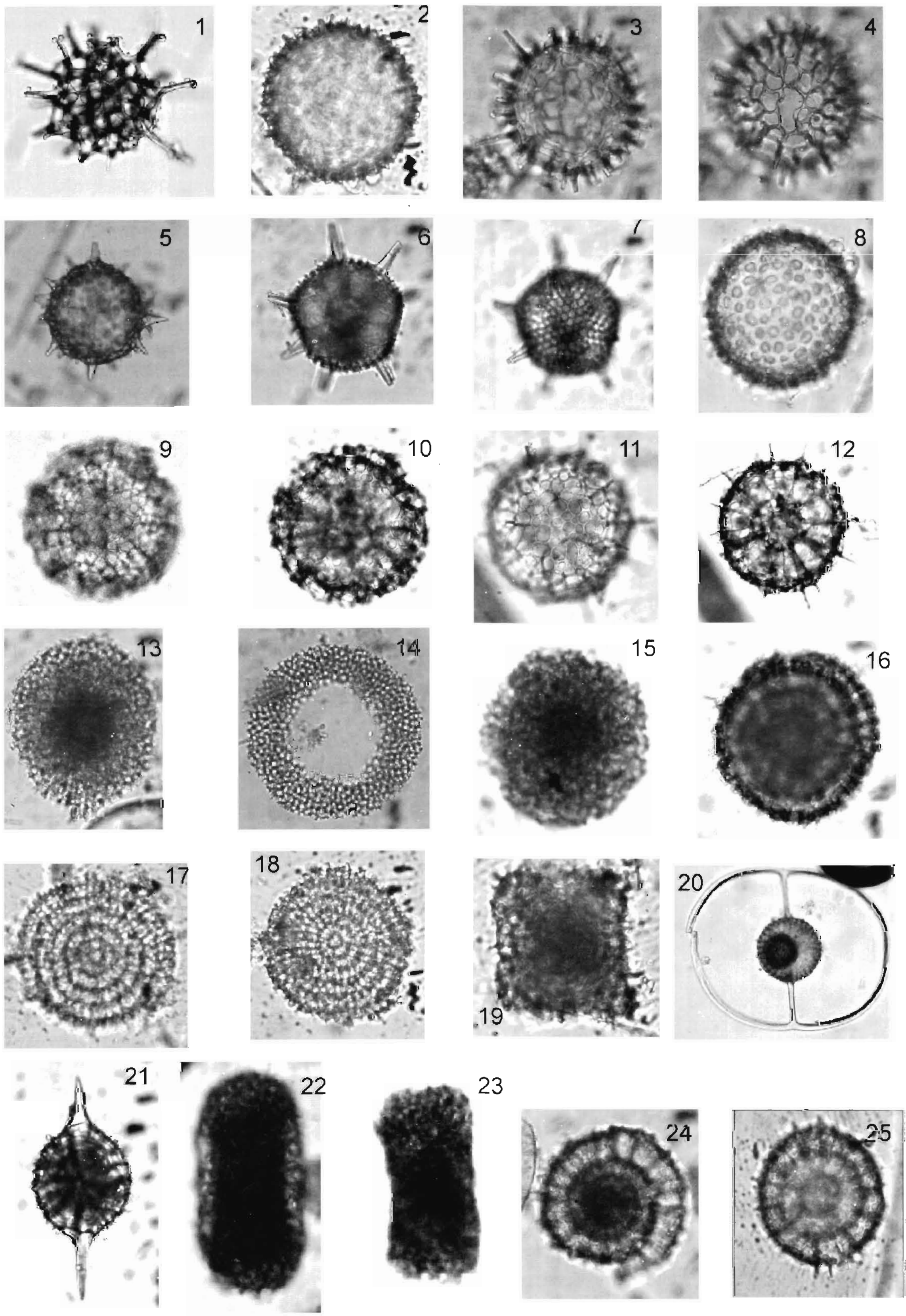
22. ***Spongurus pylomaticus*** Riedel, 745B-1H-1, 13-15; focussed on surface; x 100.

23. ***Spongurus*** sp., 745B-1H-3, 89-91; focussed on surface; x 100.

24. ***Lithelius nautiloides*** Popofsky, 745B-1H-2, 88-90; focussed on surface; x 200.

25. ***?Prunopyle antarctica*** Dreyer, 745B-1H-1, 13-15; focussed on surface; x 500.

Plate I



Spongopyle osculosa Dreyer, 1889, p.42, pl.11, figs, 99,100. Nigrini and Moore, 1979, p.S115, pl.15, fig.1.

Abundance: Very rare to few.

Range: Chen (1975a) and Keany (1979) reported its presence in Neogene.

Distribution: Sharma and Takahashi (in press) reported its presence from very rare to few in the Antarctic region. Sharma *et al.* (2004) showed its abundance from rare to abundant in the Tasman region.

Genus ***Spongotrochus*** Haeckel, 1860

Spongotrochus glacialis Popofsky group

(Pl. I, figs. 14,15)

Spongotrochus glacialis Popofsky, 1908, p.228, pl.26, fig.8, pl.27, fig.1, pl.28, fig.2.

Spongotrochus glacialis Popofsky group, Petrushevskaya, 1975, p.575, pl.5, fig.8, pl.35, figs.1-6, (with synonymy).

Abundance: Few to common.

Range: Petrushevskaya, 1975 (Miocene to Recent); Chen, 1975a (Neogene and Oligocene ?); Keany, 1979 (Neogene).

Distribution: Riedel (1958) reported its occurrence in the Antarctic region, while Lozano (1974) showed its presence in the subantarctic region. Benson (1966) considered it a cosmopolitan species. Sharma *et al.* (2004) also reported its presence from rare to abundant in the Pleistocene sediments of Tasman region. Sharma and Takahashi (*in press*) showed its presence in the Antarctic region from very rare to abundant.

Genus ***Stylodictya*** Ehrenberg, 1847a,b *emend.* Petrushevskaya and Kozlova, 1972.

Stylodictya aculeata Jörgensen

(Pl. I, fig. 17)

Stylodictya aculeata Jörgensen, 1905, p.119, pl.10, fig.41. Nigrini and Moore, 1979, p.S101, pl.13, figs.3,4.

Remarks: Differs from *S. aculeata* Jörgensen in lacking the irregular outer chambers.

Abundance: Very rare to few.

Distribution: Sharma and Takahashi (*in press*) showed its presence from very rare to few in the Antarctic region.

Stylodictya validispina Jörgensen

(Pl. I, fig. 18)

Stylodictya validispina Jörgensen, 1905, p.119, pl.10, fig.40. Nigrini and Lombari, 1984, p.S71, pl.10, fig.2.

Abundance: Very rare to few.

Range: Neogene Keany and Kennett (1975) and Keany (1979)

Distribution: Lombari and Boden (1985) reported its distribution around the Tasman region. Sharma and Takahashi (*in press*) showed its presence from very rare to few in the Antarctic region.

Family **Pyloniidae** Haeckel, 1881

Genus ***Prunopyle*** Dreyer, 1889

?Prunopyle antarctica Dreyer

(Pl. I, fig. 25)

?Prunopyle antarctica Dreyer, 1889, p.24-25, pl.5, fig.75. Chen, 1975a, p.454, pl.23, fig. 5,6.

Abundance: Very rare to few.

Range: Pleistocene to Recent (Chen,1975a).

Distribution: Riedel (1958) and Petrushevskaya (1967) reported this species from the Antarctic and subpolar regions. Chen (1975) also showed its presence in the Pleistocene sediments of the Antarctic. Sharma and Takahashi (*in press*) also showed its presence from very rare to few in the Antarctic region.

Prunopyle sp.

(Pl. II, fig. 7)

Description: Shell consisting of two concentric shells, connected by numerous radial bars. Pores of the inner shell are circular and of variable size. The outer shell has small and circular pores. The outer shell is thick and ridged. Short, thorn-like spines are sparsely distributed over the shell surface. Spines on the pylome are not very large.

Abundance: Very rare to few.

Family **Litheliidae** Haeckel,1862

Genus ***Lithelius*** Haeckel,1862

Lithelius minor Jörgensen

(Pl. I, fig. 16)

Lithelius minor Jörgensen, 1900, p.65, pl.5, fig.24. Nigrini and Lombari, 1984, p.S95, pl.14, figs.1a,b.

Abundance: Very rare to few.

Distribution: Lombari and Boden (1985) showed the widespread distribution of *L.minor* near the Antarctic region. Sharma and Takahashi (*in press*) also showed its presence from very rare to few in the Antarctic region.

Lithelius nautiloides Popofsky

(Pl. I, fig. 24)

Lithelius nautiloides Popofsky, 1908, p.230-231, pl.XXVII, fig.4. Popofsky,Nigrini and Moore, 1979, p.S137, pl.17, fig.5.

Abundance: Rare to few.

Range: Pliocene to Recent (Chen,1975a and Keany,1979). Hays (1965) reported *L. nautiloides* to be endemic to the present day Antarctic fauna.

Distribution: Sharma and Takahashi (*in press*) showed its distribution from very rare to common in the Antarctic region.

Suborder **Nassellaria** Ehrenberg, 1875

Family **Plagoniidae** Haeckel, 1881, emend. Riedel, 1967b

Genus ***Antarctissa*** Petrushevskaya, 1967

Antarctissa cylindrica Petrushevskaya

(Pl. II, figs. 17,18)

Antarctissa ewingi Chen, 1974, p.486, pl.3, figs.4-6; 1975, p.457, pl.16, fig.5-9.

Antarctissa cylindrica Petrushevskaya, 1975, p.591, pl.11, figs.19,20.

Abundance: Few to common.

Range: Lazarus (1990) reported *A. cylindrica* as its last appearance in the Psi zone. Lazarus (2002) showed its occurrence as LO-0.6, FO- 6.4Ma in the Antarctic region.

Distribution: Sharma and Takahashi (*in press*) reported this species as very rare to common from the Pleistocene sediments of Antarctica.

Antarctissa denticulata (Ehrenberg)

(Pl. II, fig. 21)

Lithobotrys denticulata Ehrenberg, 1844a, p.203.

Antarctissa denticulata (Ehrenberg), Petrushevskaya, 1968, p.84-86, fig.49,I-IV. Petrushevskaya, 1975, p.591.

Abundance: Few to common.

Range: Petrushevskaya (1975) reported its range from the Pleistocene to the Recent whereas Chen (1975a) assigned it from the Pliocene to the Pleistocene and Keany (1979) reported its range from Pliocene to Recent from the Antarctic region. Lazarus (2002) showed its presence as LO-0, FO-2.6Ma in the Antarctic region.

Distribution: This species occurs as rare to very abundant in the Pleistocene sediments of the Antarctic region, (Sharma and Takahashi, *in press*).

Antarctissa strelkovi Petrushevskaya

(Pl. II, figs. 19,20)

Antarctissa strelkovi Petrushevskaya, 1968, p.88-90, fig.51, III-VI.

Abundance: Very rare to common.

Range: Petrushevskaya (1975) reported its occurrence from the Miocene-Recent, whereas Chen (1975a) and Keany (1979) showed its presence from Pliocene to Recent. lazarus (2002) showed its occurrence as LO-0 to FO-2.5Ma in the Antarctic region.

Distribution: Sharma and Takahashi (*in press*) showed its presence from very rare to common in the Pleistocene sediments of the Antarctic region.

Genus ***Mitrocalpis*** Haeckel, 1881

Mitrocalpis araneafera Popofsky

(Pl. II, figs. 4,5)

Mitrocalpis araneafera Popofsky, 1908, 273-274, pl. 30, fig. 11. Riedel,1958, p.232, pl.3, figs.3,4, text fig.4.

Abundance: Very rare to rare.

Range: Pliocene to Recent (Chen, 1975a). Lazarus (2002) showed its occurrence in the Antarctic region as LO-0 to FO-0.9Ma.

Distribution: Sharma and Takahashi (*in press*) also reported this species as very rare from the Antarctic region.

Family **Theoperidae** Haeckel, 1881, *emend.* Riedel, 1967b.

Genus ***Cycladophora*** Ehrenberg, 1872, *emend.* Lombari and Lazarus, 1988

Cycladophora bicornis amphora Lombari and Lazarus

(Pl. II, figs. 23,24)

Cycladophora bicornis amphora Lombari and Lazarus 1988, p.110, pl.4, figs.6-12.

Remarks: In the studied section, this species has the spines on the lower and upper parts of the thorax.

Abundance: Very rare to few.

Range: Neogene (Keany,1979)

Cycladophora bicornis bicornis Popofsky

(Pl. II, figs. 10,11)

Pterocorys bicornis Popofsky, 1908, p.228, pl. 34, fig. 7,8.

Cycladophora bicornis bicornis Lombari and Lazarus 1988, p.106, pl.5, figs.9-12.

Abundance: Very rare to few.

Range: Neogene (Keany, 1979)

Distribution: Sharma and Takahashi (*in press*) reported *C. bicornis bicornis* as very rare to few in the Antarctic region.

Cycladophora davisiana Ehrenberg

(Pl. II, figs. 13)

Cycladophora davisiana Ehrenberg, 1872b, pl.II, fig.11. Lombari and Lazarus,1988, p.101.

Abundance: Very rare to few.

Range: Pliocene to Recent (Keany,1979)

Distribution: Riedel (1958) considered this species to be cosmopolitan and showed more abundance in high latitudes than at lower latitudes. Lombari and Boden (1985) showed its presence throughout the region and also considered cosmopolitan species. Sharma and Takahashi (*in press*) showed its presence from very rare to common in the Antarctic region.

Cycladophora robusta Lombari and Lazarus

(Pl. II, figs. 8,9)

Cycladophora robusta Lombari and Lazarus,1988, p.105, pl.2, fig.1-14.

Remarks: *C. robusta* is having the morphology of larger lower thorax and well-developed abdomen compared to *C. davisiana* Lombari and Lazarus(1988).

Abundance: Rare to few.

Genus ***Cyrtopera*** Haeckel,1881

Cyrtopera laguncula Haeckel

(Pl. II, fig. 6)

Cyrtopera laguncula Haeckel, 1887, p.1451, pl.75, fig.10. Chen, 1975a, p.460, pl.18, fig.9.

Abundance: Very rare.

Range: Neogene (Chen,1975a)

Distribution: Chen (1975a) reported its presence in higher latitudes. Sharma and Takahashi (*in press*) showed its presence as very rare to few in the Pleistocene sediments of the Antarctic region.

Genus ***Dictyophimus*** Ehrenberg, 1847a

Dictyophimus mawsoni Riedel

(Pl. II, fig. 16)

Dictyophimus mawsoni Riedel, 1958, p. 234, pl. 3, figs. 6,7. Chen, 1975a, p.460, Pl.19, Figs.1,2.

Abundance: Very rare to few.

Range: Pliocene to Recent (Chen,1975a).

Distribution: Sharma and Takahashi (*in press*) showed its occurrence as very rare to few from the Antarctic region.

Family **Acropyramididae** Haeckel,1881

Genus ***Litharachnium*** Haeckel, 1860 b

Litharachnium tentorium aff. *L. tentorium* Haeckel

(Pl. II, fig. 14)

Litharachnium tentorium Haeckel, 1860b, p.839. Takahashi, 1991 p.114, pl. 35, figs. 14-18; Okazaki *et al.*, 2004, pl. 2, figs, 29, 30.

Remarks: The reported from is very similar to that illustrated by Takahashi (1991) but differs in not having large abdominal part, rods and pore framework.

Abundance: Very rare

Range: Lazarus (2002) reported its occurrence (FO–0, LO–0.7Ma) from the Antarctic Neogene sediments.

Genus ***Peripyramis*** Haeckel,1881

Peripyramis circumtexta Haeckel

(Pl. II, fig. 15)

Peripyramis circumtexta Haeckel, 1887, p.1162, pl.54, fig.5. Nigrini and Moore, 1979, p.N29, pl.21, figs.4a,b

Abundance: Very rare to few.

Range: Miocene(?) - Recent (Petrushevskaya, 1975), Neogene (and Oligocene) Chen (1975a) and Neogene (Keany, 1979).

Distribution: Sharma and Takahashi (in press) reported its distribution from very rare to few in the Pleistocene sediments of Antarctic region.

Genus ***Plectopyramis*** Haeckel, 1881

Plectopyramis dodecomma Haeckel

(Pl. II, fig. 22)

Plectopyramis dodecomma Haeckel 1887, p.1258, p.54, fig.6. Nigrini and Moore,1979. p.N31, pl.21, fig. 5.

Remarks: Similar to the forms illustrated by Nigrini and Moore (1979).

Abundance: Very rare to rare.

Range: Neogene (Keany,1979).

Family **Artostrobiidae** Riedel,1967a, emend. Foreman,1973

Genus ***Botryostrobus*** Haeckel, 1887 emend. Nigrini,1977.

Botryostrobus sp. A

(Pl. II, fig. 26)

Description: Shell spindle shaped having six segments separated by round constrictions with transverse rows of pores. Fourth segment widest and having two rows of horizontal pores. Cephalis does not have apical horn and vertical tube. Smooth termination present in the cephalis part.

Abundance: Very rare

Botryostrobus sp. B
(Pl. II, fig. 25)

Description: Shell heavy, thick walled with five segments. Third segment is widest and has three transverse rows of pores. Small apical horn is obliquely directed upwards. Distally, shell is narrow and having a single row of pores. Smooth termination present.

Abundance: Very rare.

RADIOLARIAN BIOSTRATIGRAPHY

Well-preserved, abundant and highly diverse radiolarian assemblages were found in the sections (1H and 2H) of Leg 119. The radiolarian fauna is typical of Antarctic assemblage. The basis for Pleistocene Antarctic radiolarian zonations is that of Hays (1965), Hays and Opdyke (1967), Chen (1975) and modified by Weaver (1983), Caulet (1982, 1985, 1986) and Lazarus (1990, 1992, 2002).

Two radiolarian zones (Fig.2) are established in the two sections, i.e. Psi and Omega on the basis of last appearance, consistent appearance and highest common occurrence of radiolarian taxa. Lazarus (1990) defined Omega zone (~0.43Ma-Recent) base as the last appearance of *Stylatractus universus*. In the studied sequence, its last appearance is in the sample 745B-2H-2,13-15 as single specimen and further it is present in the section 3H. Lazarus (2002) reported last *S. universus* occurrence of at 0.3 and first occurrence at 13.2 Ma in the Antarctic region. However, the authors have followed the radiolarian zonation proposed by Lazarus (1990).

Lazarus (1990) defined the Psi zone (~0.8-0.4Ma) top as the last appearance of *S. universus* Hays 1970. However, it is continued further in the lower part of the sections of the core. Hays and Opdyke (1967) considered the *Antarctissa cylindrica* Petrushevskaya 1975 as better marker for this zone and is generally found as abundant. In the studied section, *A. cylindrica* shows its consistent presence from common to few. Lazarus (2002) reported the last and first occurrence of *Dictyophimus mawsoni* (LO -0.9; FO-0.6) from the Antarctic region. However, in the core, it is present from 745B-2H-2, 88-90 as single specimen to rare in 745B-2H-6,13-15. It is observed that the sections (1H and 2H) of Leg 119 are of upper Pleistocene (between 0.8 Ma and Recent). Berggren *et al*, 1985 considered these sections of Brunhes epoch.

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EXPLANATION OF PLATE II

1,2. ***Stylatractus universus*** Hays, 745B-2H-2, 88-90; focussed on inner and outer portion ; x 200.

3. ***Spongocore*** sp., 745B-2H-5, 88-90; focused on surface; x 200.

4,5. ***Mitrocalpis aranefera*** Riedel 745B-2H-3, 13-15; 4. focussed on pore pattern 5. focussed on outer portion; x 200.

6. ***Cyrtopera laguncula*** Haeckel, 745B-1H-1, 13-15; focussed on surface; x 200.

7. ***Prunopyle*** sp., 745B-1H-4, 13-15; focussed on surface; x 200.

8,9. ***Cycladophora robusta*** Lombari and Lazarus, 745B-1H-2, 88-90; 14. focussed on surface; x 100, 745B-1H-3, 88-90; 15. focussed on inner portion; x 100.

10,11. ***Cycladophora bicornis bicornis*** Popofsky, 745B-2H-5, 13-15; 10 focussed on surface 11. focused on inner surface; x 200.

12. ***Heliosoma*** sp., 745B-1H-3, 88-91; focussed on surface; x100.

13. *Cycladophora davisiana* Ehrenberg, 745B-1H-2, 88-90; focussed on surface; x 100.

14. ***Litharachnium tentorium*** aff. ***L. tentorium*** Haeckel, 745B-1H-2, 88-90; focused on surface; x 500.

15. ***Peripyramis circumtexta*** Haeckel, 745B-1H-2, 13-15; focused on surface; x 500.

16. ***Dictyophimus mawsoni*** Riedel, 745B-2H-2, 88-90; focused on surface; x 100.

17,18. ***Antarctissa cylindrica*** Ehrenberg, 745B-2H-6, 13-15; 17.focussed on surface; 18. focussed on pores; x 500.

19,20. ***Antarctissa strelkovi*** Petrushevskaya, 745B-1H-3, 13-15; 18. focussed on outer portion; x 100. 19. focussed on inner portion; x200.

21. ***Antarctissa denticulata*** Ehrenberg, 745B-1H-1, 13-15; focussed on surface; x 200.

22. ***Plectopyramis dodecomma*** Haeckel, 745B-2H-2, 88-90; focussed on surface; x 100.

23,24. ***Cycladophora bicornis amphora*** Lombari and Lazarus, 745B-1H-3, 89-91; 23. focussed on inner portion 24. focussed on outer portion; x 100.

25. ***Botryostrobus*** sp. B, 745B-2H-4, 88-90; focused on surface; x 500.

26. ***Botryostrobus*** sp. A, 745B-2H-5, 88-90; focused on surface; x 500.

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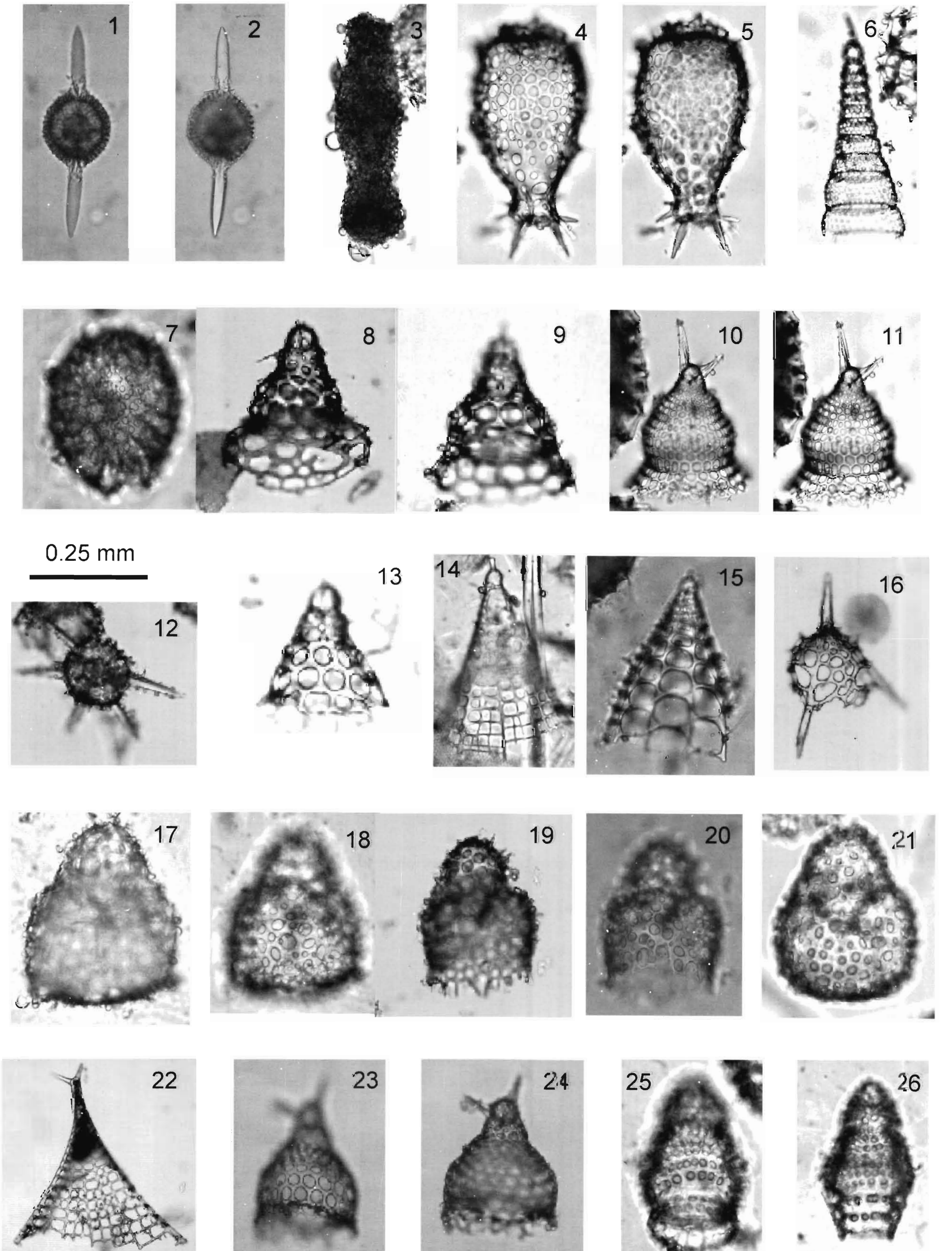
Plate II



SHARMA AND BORA

Table 1: Occurrences of Radiolarian species in the samples (VA=very abundant (<50%); A=abundant (20-50%); C=common (5-20%); F=few(0.5-5%); R=rare(<0.5%), but more than single specimen; += single specimen; - = absent) and preservation (G=good).

a	Sample Name(Hole.Core.Section.Interval(cm)	745B-1H-1.13-15	745B-1H-1.88-90	745B-1H-2.13-15	745B-1H 2.88-90	745B-1H-3.13-15	745B-1H-3.89-91	745B-1H-4.13-15	745B-2H-1.43-45	745B-2H-1.96-98	745B-2H-2.13-15	745B-2H-2.88-90	745B-2H-3.13-15	745B-2H-3.88-90	745B-2H-4.13-15	745B-2H-4.88-90	745B-2H-5.13-15	745B-2H-5.88-90	745B-2H-6.13-15	745B-2H-6.93-95	745B-2H-7.11-13
b	Depth (mbsf)	0.13	0.88	1.63	2.38	3.13	3.89	4.63	5.43	5.96	6.63	7.38	8.13	8.88	9.63	10.38	11.13	11.88	12.63	13.43	14.11
c	Age		U	P	P	E	R			P	L	E	I	S	T	O	C	E	N	E	
d	Radiolarian Zone			O	M	E	G	A						P	S	I					
e	Abundance	VA	C	A	VA	C	VA	C	C	C	A	A	VA	A	C	VA	A	VA	A	VA	A
f	Preservation	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
	Name of Species																				
1	Acanthosphaera sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	Acrosphaera sp. cf A. spinosa echinoides	F	F	-	-	R	-	-	R	-	-	F	F	F	-	F	F	R	F	-	-
3	Acrosphaera sp. A.	F	F	-	F	F	F	-	-	-	-	-	R	-	R	R	-	-	-	-	-
4	Acrosphaera sp.B.	F	-	-	R	R	F	-	+	-	-	-	-	-	-	-	-	-	-	-	-
5	Actinomma antarcticum	F	F	F	F	F	F	-	F	C	-	F	-	F	F	F	F	F	-	R	-
6	Actinomma leptodermum	-	-	-	R	F	-	-	-	-	-	R	-	-	+	F	-	-	-	-	-
7	Antarctissa cylindrica	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	C	C	C	F	C
8	Antarctissa denticulata	C	C	F	F	C	C	F	F	F	F	F	F	F	F	C	C	C	C	F	F
9	Antarctissa strelkovi	F	C	F	C	C	C	F	F	-	F	F	F	C	F	C	F	F	C	F	F
10	Botryostrobus sp. A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	Botryostrobus sp B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	Cycladophora bicornis amphora	F	F	R	-	-	F	-	R	-	R	-	-	-	-	-	-	-	-	R	-
13	Cycladophora bicornis bicornis	-	F	-	-	-	-	-	-	-	F	-	-	-	-	R	-	-	-	R	-
14	Cycladophora davisiana	-	F	R	F	F	F	F	-	-	-	-	F	R	-	R	-	R	-	-	R
15	Cycladophora robusta	F	F	F	F	F	F	F	F	-	F	F	F	F	-	F	-	F	F	R	F
16	Cyrtopera laguncula	+	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17	Dictyophimus mawsoni	+	-	-	-	-	-	-	-	-	-	-	-	R	-	-	+	-	-	-	-
18	Haliommetta miocenica	-	-	F	F	F	F	-	-	-	-	R	F	F	F	F	F	-	-	-	-
19	Helicosoma sp.	-	+	-	-	F	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20	Litharachnium tentorium aff. L. tentorium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21	Lithelius minor	R	F	F	F	F	F	-	-	-	-	F	F	F	R	F	F	F	F	F	F
22	Lithelius nautiloides	F	F	F	F	F	F	R	F	-	F	F	F	F	F	F	F	F	F	F	F
23	Mitrocalpis aranefera	-	-	-	-	-	-	-	-	-	-	-	-	R	-	R	-	-	-	-	-
24	Peripyramis circumtexta	R	R	-	F	F	R	-	-	-	-	F	F	R	-	R	-	-	-	-	-
25	Plectopyramis dodecomma	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-
26	Prunopyle antarctica	F	F	F	F	F	F	R	R	-	-	-	-	-	-	R	F	R	-	-	-
27	Prunopyle sp.	F	F	-	R	F	F	F	-	-	-	-	R	F	-	F	F	F	-	R	R
28	Saturnalis circularis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
29	Spongaster tetras irregularis	F	F	F	F	F	F	F	-	-	-	-	-	-	-	R	-	F	-	-	F
30	Spongocore sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
31	Spongopyle osculosa	F	F	-	R	-	R	-	F	-	R	F	F	F	-	F	F	F	R	F	F
32	Spongotrochus glacialis	F	C	C	F	C	F	F	C	F	F	C	C	C	C	C	F	F	F	F	C
33	Spongurus pylomaticus	F	F	F	F	C	F	F	F	-	-	F	F	F	-	F	F	R	R	F	R
34	Spongurus sp.	F	F	-	F	F	R	F	R	-	-	R	F	F	-	R	F	R	-	R	-
35	Stylatractus universus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
36	Stylatractus sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
37	Stylodictya aculeata	-	F	-	R	F	F	R	-	-	-	-	-	-	-	-	-	F	-	-	R
38	Stylodictya validispina	R	F	-	-	F	R	-	-	-	-	-	R	R	-	R	-	F	-	-	-

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